Systematic Review of Collaborative Learning Influencing Factors and Outcomes in Primary Science Education

Bingxue Liu[a], Ying Xu[b], Ziqian Wan[c*]

Faculty of Artificial Intelligence in Education Central China Normal University
Wuhan, China

[a]2817444383@qq.com, [b]3221789264@qq.com,
[c*]wan.ziqian@ccnu.edu.cn

Abstract. This literature review provides a systematic synthesis of research on collaborative learning in primary science education from 2014 to 2024. It examines effective strategies and student outcomes, focusing on upper elementary grades with a variety of methodological approaches. The review identifies strategies that enhance cognitive, affective, and social competencies in students, categorized under Personal Factors, Behavioral Patterns, and Environmental Influences. Personal Factors include individual attributes such as leadership and regulatory skills. Behavioral Patterns involve group dynamics and interactions, while Environmental Influences encompass teaching strategies, technology support, and cultural factors. Collaborative learning significantly impacts student competencies, fostering cognitive improvements in conceptual understanding and problem-solving, affective gains in motivation and self-confidence, and social development in communication and cooperation. Despite these positive findings, the review acknowledges certain limitations, such as the dominance of English-language studies and a reliance on case studies. It recommends that future research explore the long-term effects and scalability of collaborative learning across diverse educational contexts. The review concludes by underscoring the importance of continued innovation in collaborative learning to enhance student engagement and academic success.

Keywords: collaborative learning; primary school students; science education

1 Introduction

In the context of global development, science education faces growing demands and challenges, including the need for interdisciplinary integration, the cultivation of 21st-century skills, and technology integration in educational settings worldwide [1][2]. Collaborative learning has emerged as a vital strategy to address these challenges and is increasingly emphasized in primary science activities [3]. Educators and researchers advocate for its adoption to better prepare students for future challenges.

In contemporary educational landscapes, collaborative learning is tightly interwoven with innovative pedagogical approaches. Practices like Problem-Based Learning

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(PBL), Project-Based Learning (PjBL), and Cooperative Inquiry are frequently underpinned by extensive case studies. These studies have distilled a range of effective strategies aimed at enhancing collaborative learning within the classroom. For example, a study involving sixth-grade students in science inquiry activities demonstrated that the use of socially shared regulation strategies improved over time, underscoring the importance of group dynamics in successful collaboration [4]. Despite the growing enthusiasm and research in this field, the complexity and variability of classroom environments necessitate a systematic review to identify the most effective collaborative approaches from existing literature.

Besides, the heterogeneity of learning outcomes and assessments across studies further complicates the understanding of the impact of collaboration in primary science education. This diversity in focus points to a need for a comprehensive synthesis that can elucidate the multifaceted nature of collaborative learning and its outcomes. Therefore, this literature review aims to answer three pivotal research questions through a systematic examination of existing literature and thematic analysis:

(1)What grade levels and methodologies have been predominant in research on student collaboration in primary science education?

(2)What influencing factors have been identified from existing literature to improve student collaboration in primary science classrooms?

(3)What did the learning outcomes or assessments focus on in collaborative learning activities within elementary school science activities?

2 Related Work

The landscape of primary science education has been extensively surveyed in numerous literature reviews, which have primarily focused on a variety of aspects such as pedagogical strategies, curriculum development, integration of technology, and assessment methods. For instance, the review by Lai and Cheng emphasizes the integration of engineering principles through the STEM x Play program [8], highlighting the importance of developing critical skills like collaboration and problem-solving from an early age. Similarly, Garzon and Lampropoulos present a meta-analysis that underscores the significant impact of mobile learning on student learning across K-12 education [9], including the primary science classroom.

While the potential of collaborative learning has been briefly acknowledged, as in the case of the STEM x Play program which fosters comfort with failure and collaboration [8], and the situated learning approach that supports educational interventions [9] , there remains a dearth of comprehensive synthesis on this topic.

This literature review seeks to address this gap by examining the current state of research on collaborative learning in primary science education. It aims to consolidate findings from studies that have explored the effectiveness of collaborative approaches, the impact on student learning outcomes, and the influential factors that mediate this educational strategy.

3 Methodology

3.1 Literature Search

We conducted a comprehensive search in the Web of Science Core Collection database for research on collaborative activities in primary science education, focusing on articles published from 2014 to 2024. Using specific keywords: ("K-12 education" OR "primary school") AND ("collaborative" OR "cooperative" OR "pair") AND ("science" OR "STEAM" OR "STEM"), we initially identified a substantial number of articles. After narrowing this down based on titles and abstracts, we selected 32 articles for further review. Upon analyzing the full texts, we excluded 11 articles that did not meet our criteria, such as those focused on preservice teacher training or unrelated programming courses. This filtering process left us with 21 articles directly relevant to our research interests. The initial search was conducted on July 7, 2024, and the process is illustrated in the PRISMA flowchart in Figure 1. This systematic approach ensured that we concentrated on the most pertinent studies in collaborative science learning environments, providing a solid foundation for our research on collaborative activities in primary science education.

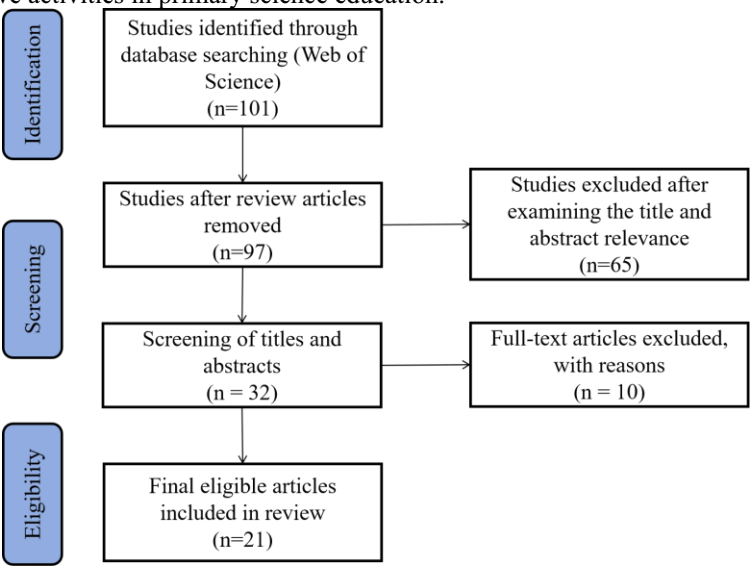

Fig. 1. PRISMA flow chart of the selection process

3.2 Data Analysis

We coded several features for comparison and synthesis across studies: (1) group size, distinguishing pairs (two persons) from larger groups (more than two); (2) education level; (3) learning environment, including STEAM classrooms, special education settings, and online platforms; (4) duration of interventions, ranging from short-term activities to long-term educational programs; and (5) research methods, including

experimental and case study research. Utilizing Bandura's Social Learning Theory [10], we establish a framework to understand the complexities of collaborative learning, emphasizing personal factors, behavioral patterns, and environmental influences. We categorized assessment dimensions into three competencies from existing Collaborative Problem Solving (CPS) frameworks: cognitive, affective, and social [11]. Cognitive competencies involve students' concept understanding, problem-solving abilities, and knowledge acquisition. Affective competencies pertain to students' attitudes and feelings in collaborative contexts. Social competencies encompass social skills exhibited during learning, such as participation, cooperation, perspective-taking, and social regulation.

4 Results

4.1 What Grade Levels and Methodologies Have Been Predominant in Research on Student Collaboration in Primary Science Education?

In the research on student collaboration in primary science education, the participants are predominantly from different grade levels of elementary school students. Based on the statistical data, the participants encompass a range of primary school grades, with representation from the sixth grade (n=10), fifth grade (n=1), fourth grade (n=3), and third grade (n=1). Additionally, there are studies that span multiple grades (n=4), indicating a broader investigation across different levels. It is important to note that two of the studies focus exclusively on primary school students without specifying particular grades. Specifically, 6th graders are the focus of the research, accounting for more than half of all studies. Although the participant demographic is diverse, comprising students from different grades, these studies indicate that research on student collaboration in primary science education mainly focuses on high-grade elementary students, but is also gradually extending to lower-grade students.

In terms of research methods, the studies mainly include case studies (n=11), experimental studies (n=9), and surveys (n=1). According to the statistical data, case studies are the most used method, with 11 studies employing this approach. Experimental studies come next, with 7 studies using this method. The only study employing a survey methodology within this context, it involves a systematic collection and analysis of existing literature, video data observation, and the development and validation of an assessment tool based on observed data [12].

4.2 What Influencing Factors Have Been Identified from Existing Literature to Improve Student Collaboration in Primary Science Classrooms?

This study is organized based on Bandura's Social Learning Theory [10], categorizing strategies into three influencing factors: Personal Factors, Behavioral Patterns, and Environmental Influences. Personal Factors refer to the individual attributes of students that can be leveraged to foster collaboration, while Behavioral Patterns involve the actions and interactions among students indicative of effective collaboration. Environmental Influences pertain to external conditions and support systems that can

enhance collaborative learning. Among the 21 selected articles, 4 address Personal Factors, 11 discuss Behavioral Patterns, and 18 explore Environmental Influences.

Within Personal Factors influencing collaboration, three secondary dimensions are identified: physiological characteristics (n=1), social and cognitive attributes (n=1), and regulatory skills (n=2). The physiological characteristics dimension highlights the necessity of accommodating students with visual impairments to create an inclusive learning environment [6]. Social and cognitive attributes play a pivotal role in shaping group dynamics; Article 7 discusses how traits such as leadership and perceptions of group tasks significantly influence learning regulation within a group setting [4]. Additionally, self-regulation and engagement in metacognitive activities are crucial for constructing new scientific knowledge [13].

Within the domain of Behavioral Patterns that influence student collaboration, the literature has identified three pivotal dimensions: Group Interactive Behavior (n=3), Group Dynamic Behavior (n=7), and Group Leader Behavior (n=1). Group Interactive Behavior emphasizes direct interactions among group members, essential for idea and resource exchange. Studies note that students engage in collaborative problem-solving within STEAM activities, which include sharing resources, assimilating knowledge, adjusting viewpoints, and maintaining positive communication [6][14]. This interaction is enhanced by techniques such as Jigsaw and Team Pair-Solo strategies, promoting active participation within the group. Group Dynamic Behavior addresses broader trends and changes within the group. Research indicates the importance of structured collaboration, role assignments, equal participation opportunities, and time management in shaping group dynamics. Although Group Leader Behavior is not explicitly labeled in the literature, the concept of shared leadership is discussed, which fosters flexible role changes and consideration of others' ideas, enhancing overall collaboration [18].

Within the realm of Environmental Influences that shape student collaboration, four secondary dimensions have emerged from the literature: Teaching Strategies (n=14), Technology Support (n=7), Teacher Guidance (n=10), and Cultural Environment (n=2). Teaching Strategies focus on interdisciplinary approaches within STEAM education, emphasizing problem-based learning and the integration of various disciplines to facilitate collaborative problem-solving [14]. Technology Support significantly enhances collaborative experiences, as illustrated by article 8, which highlights the interactive features of platforms like wikis. These features, including real-time editing and feedback, are vital for student engagement [16]. Teacher Guidance is crucial in shaping collaborative processes; one study underscores the importance of teacher support in guiding role assignments and negotiations, essential for successful collaborative tasks [15]. Lastly, the Cultural Environment affects social and emotional interactions within a group. Article 8 discusses how collectivism in Asian cultures may foster interaction and cooperation among students in online learning settings [16]. By understanding and integrating these Environmental Influences, educators can create rich learning environments that support and enhance student collaboration in primary science classrooms.

4.3 What Did the Learning Outcomes or Assessments Pay Attention to in Collaborative Learning Activities Within Elementary School Science Activities?

This examination of learning outcomes in elementary school science activities is structured using Collaborative Problem Solving (CPS) frameworks, focusing on three primary dimensions of competencies: Cognitive, Affective, and Social. Cognitive competencies involve intellectual and mental skills, Affective competencies address emotional and motivational aspects, and Social competencies focus on interpersonal and interactional skills developed through collaboration. Among the 21 reviewed articles, 19 emphasize Cognitive aspects, 12 discuss Affective aspects, and 9 address Social aspects.

Cognitive competencies encompass six secondary dimensions. Conceptual understanding and knowledge acquisition appear prominently, with 11 studies showing that collaborative strategies enhance students' grasp of scientific concepts and knowledge. Problem-solving and cognitive skill development are similarly highlighted in 11 studies, which demonstrate that collaboration improves students' abilities to solve problems, reach shared understandings, and organize team efforts effectively. Innovation and creative thinking, discussed in 3 studies, emphasize creativity in designing solutions and applying STEM concepts [16][18][21]. Four studies indicate that collaborative learning supports technical proficiency and scientific inquiry skills, particularly in robotics education [5][15]. Additionally, 4 studies highlight improved academic performance and independent learning through collaborative efforts, particularly in social studies [20].

Affective competencies, derived from 12 studies, play a crucial role in the collaborative learning experience. Motivation and interest enhancement are discussed in 4 studies, which show that methods like Jigsaw and Team Pair-Solo increase students' interest in science [6]. These strategies also improve attitudes and self-confidence, particularly among students with visual impairments. Five studies emphasize self-confidence, self-efficacy, and positive learning attitudes, showing enhancements in students' academic self-perception [7]. Social shared regulation of motivation and emotion also plays a key role in fostering proactive engagement [4]. Six studies find that a positive socio-emotional climate enhances group cohesion and motivation, essential for successful collaboration [13][19]. Furthermore, engagement and satisfaction, discussed in 7 studies, correlate strongly with academic performance and assessments [15][19].

Social competencies are highlighted in 9 studies. Team interaction and communication skills are emphasized, with 3 studies noting improvements through active communication and listening within teams [14][21]. These skills are crucial in facilitating multipath exploration and interdisciplinary thinking, particularly in STEAM activities [14]. Social skills such as negotiation, conflict resolution, and respect for diversity are emphasized in 5 studies, demonstrating their importance in collaborative settings [16][17]. Structured strategies like SsRL further enhance collaborative interactions and dialogue [4]. Three studies underscore improvements in collaborative

competence and coordination, showing that project-based activities help students develop teamwork skills through experiment design and result analysis [5][19].

5 Discussion

Research on student collaboration in primary science education identifies several predominant collaborative learning approaches categorized into three dimensions: personal factors, behavioral patterns, and environmental influences.

Personal factors significantly shape collaborative learning outcomes. For instance, students with visual impairments need inclusive environments tailored to their needs [6]. Moreover, social and cognitive attributes such as leadership and role understanding are crucial for effective group dynamics [4]. Regulatory skills, including self-regulation, co-regulation, and shared regulation, are essential for managing behaviors, emotions, and cognitive processes during collaboration [4]. Behavioral patterns also play a vital role in effective collaboration. Group interactive behaviors, like sharing resources and ideas, facilitate idea exchange [14]. Additionally, group dynamic behaviors, which involve structured collaboration, role assignments, equal participation, and time management, enhance the collaborative learning experience [17]. Leadership behaviors, especially shared leadership, promote effective collaboration by encouraging flexible role changes and valuing diverse ideas [18].

Environmental influences significantly impact collaborative learning. Effective teaching strategies, such as interdisciplinary approaches in STEAM education and instructional methods like Jigsaw and Team Pair-Solo, contribute to dynamic learning environments [6]. The integration of technology, including interactive platforms like wikis and mobile learning tools, enhances collaborative experiences and outcomes [16][20]. Furthermore, teacher guidance—such as support for role assignments, negotiations, emotional support, and scaffolding—plays a crucial role in successful collaborative tasks [7][17]. Cultural factors, notably collectivism in Asian cultures, also foster interaction and cooperation among students in online settings [16].

The literature indicates that collaborative learning activities in elementary science develop various competencies. Cognitive competencies include conceptual understanding, problem-solving, and innovation. Affective competencies encompass motivation, self-confidence, and emotional experiences, while social competencies involve team interaction, communication skills, and collaborative competence.

Future research should explore the interplay of these factors, conduct comparative and longitudinal studies, examine cultural variations, and create comprehensive evaluation frameworks. This will enable educators to design more effective collaborative learning experiences that enhance student engagement and academic success.

6 Conclusion

This literature review synthesizes contemporary research on collaborative learning in primary science education from 2014 to 2024. It highlights diverse methodologies,

including case studies, experimental studies, and surveys, organized around Bandura's Social Learning Theory [10].

The review identifies strategies enhancing collaboration, categorized as Personal Factors, Behavioral Patterns, and Environmental Influences, linked to improved cognitive competencies (conceptual understanding, problem-solving) and affective/social competencies (motivation, self-confidence, communication). A key finding is the significant impact of collaborative learning on developing these competencies. The importance of inclusive, supportive environments fostering active participation and critical thinking is emphasized.

However, limitations exist: the focus on English-language studies may restrict perspectives from non-English contexts, and the predominance of case studies might overlook other valid methodologies. Additionally, the emphasis on higher-grade students may neglect younger learners. While positive outcomes of collaborative learning are highlighted, more research is needed on long-term effects and scalability in diverse educational settings. The review also identifies a gap in understanding which collaborative techniques are most effective for varying student populations and learning objectives.

In conclusion, it offers valuable insights for future research and educational practices in collaborative learning.

References

1. Bybee, R. W. (2013). The next generation science standards and the life sciences. Science Teacher, 80(2).
2. Osborne, J. (2013). The 21st century challenge for science education: Assessing scientific reasoning. Thinking skills and creativity, 10, 265-279.
3. Moreno, N. P. (1999). K-12 science education reform—a primer for scientists. BioScience, 49(7), 569-576.
4. Ucan, S. (2017). Changes in primary school students' use of self and social forms of regulation of learning across collaborative inquiry activities. International Journal of Educational Research, 85, 51-67.
5. King, D., & English, L. D. (2016). Engineering design in the primary school: Applying STEM concepts to build an optical instrument. International Journal of Science Education, 38(18), 2762-2794.
6. Nnamani, O., Hadebe-Ndlovu, B. N., Okeke, C. I., & Ede, M. O. (2023). Effect of Jigsaw and Team Pair-Solo cooperative learning strategies on interest in Basic Science of primary school children with visual impairment. Psychology in the Schools, 60(7), 2430-2446.
7. Burak, D., & Gultekin, M. (2024). Implementation and Evaluation of an Adaptive Learning Environment Designed According to Learner Characteristics: A Study on Primary School Social Studies Teaching. Technology, Knowledge and Learning, 29(1), 163-196.
8. Lai, M. Y., & Cheng, E. (2023, November). Bringing engineering into primary science classrooms using engineering design and community of practice approach—An evaluation of STEM× Play program. In Frontiers in Education (Vol. 8, p. 1290857). Frontiers Media SA.
9. Garzón, J., & Lampropoulos, G. (2023). Mobile learning for science education: meta-analysis of K-12 research. Interactive Learning Environments, 1-16.

10. Bandura, A. (1969). Social-learning theory of identificatory processes. Handbook of socialization theory and research, 213, 262.
11. Bloom, B. S. (1956). Taxonomy of Educational Objectives, Handbook I: The Cognitive Domain. New York: David McKay Co Inc.
12. Herro D, Quigley C, Andrews J, et al. Co-Measure: developing an assessment for student collaboration in STEAM activities[J]. International journal of STEM education, 2017, 4: 1-12.
13. Mänty, K., Järvenoja, H., & Törmänen, T. (2023). The sequential composition of collaborative groups' emotion regulation in negative socio-emotional interactions. European Journal of Psychology of Education, 38(1), 203-224.
14. Herro, D., & Co-Measure, C. Q. (2017). develo** an assessment for student collaboration in STEAM activities [Электронный ресурс]. International Journal of STEM Education.
15. Zhong, B., Liu, X., & Huang, Y. (2023). Effects of pair learning on girls' learning performance in robotics education. Journal of Educational Computing Research, 61(1), 151-177.
16. Lau, W. W., Lui, V., & Chu, S. K. (2017). The use of wikis in a science inquiry-based project in a primary school. Educational Technology Research and Development, 65(3), 533-553.
17. Ouyang, F., Dai, X., & Chen, S. (2022). Applying multimodal learning analytics to examine the immediate and delayed effects of instructor scaffoldings on small groups' collaborative programming. International Journal of STEM Education, 9(1), 45.
18. Bassachs, M., Cañabate, D., Serra, T., & Colomer, J. (2020). Interdisciplinary cooperative educational approaches to foster knowledge and competences for sustainable development. Sustainability, 12(20), 8624.
19. Carroll, A., Gillies, R. M., Cunnington, R., McCarthy, M., Sherwell, C., Palghat, K., ... & Seary, T. (2019). Changes in science attitudes, beliefs, knowledge and physiological arousal after implementation of a multimodal, cooperative intervention in primary school science classes. Information and Learning Sciences, 120(7/8), 409-425.
20. Zhong, B., Wang, Q., Chen, J., & Li, Y. (2017). Investigating the period of switching roles in pair programming in a primary school. Journal of Educational Technology & Society, 20(3), 220-233.
21. Zhang, Z., Bekker, T., Markopoulos, P., & Skovbjerg, H. M. (2024). Supporting and understanding students' collaborative reflection-in-action during design-based learning. International Journal of Technology and Design Education, 34(1), 307-343.